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DEPARTMENT OF MINES AND RESOURCES

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GEOLOGICAL INVESTIGATIONS ALONG THE ALASKA HIGHWAY FROM FORT NELSON, BRITISH COLUMBIA, TO WATSON LAKE, YUKON

(Report and Map)

BY

M. Y. Williams

OTTAWA

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INTRODUCTION

Field Work and Acknowledgments

The field season began on June 1 and closed on September 25. Of this period, June 17 to September 17 was spent in the field of investigation, the remainder of the time being occupied with preparations in Edmonton and in travelling. Long delays occurred during periods when sections of road were closed to traffic.

The writer was ably assisted in the field by John L. DeLeen of Vancouver and F. O. Norman of Winnipeg. A. L. Rand, zoologist of the National Museum, Ottawa, was attached to the writer's party from July 19 until the end of the season. His report[1] on the zoology along

[1] Rand, A.L.: The Southern Half of the Alaska Highway and its Mammals; Nat. Mus. of Canada, Bull. No. 98.

the route travelled has been published.

The writer wishes to express warm appreciation for the cordial assistance rendered by the United States military and civil authorities, and by the various American and Canadian construction companies operating along the road. The R. Melville Smith Construction Company took efficient charge of the party's mail in both collection and delivery. The Dufferin Construction and Paving Company supplied shelter, board, and equipment during and after the flood of July 10 when supplies and tents were lost. The following construction companies also assisted in various ways: Emil Anderson, Storm's, Jupp's, Harvey's, Campbell, Bond, McNamara, Curran, and Briggs. It was only through such kind assistance that the work was carried on.

Previous Geological Work

Reports[2] by G. M. Dawson and R. G. McConnell, based upon their

[2] A bibliography of references is given at the end of this report.

historic trip of 1887, describe the general geology along Dease River, and down Liard Valley from Watson Lake. In 1922 the writer made a reconnaissance from Fort St. John northward to Sikanni Chief River at "Whipsaw Camp" (established in the winter of 1921-22 near the mouth of Buckinghorse River) and down the Sikanni and Fort Nelson to Liard River. His report and those by Dawson and McConnell are the only ones dealing directly with the geology of the region. Their conclusions as embodied in this report are duly acknowledged.

Farming, Ranching, and Gardening

Conditions are favourable near the Liard hot springs for gardening, berry raising, and small farming. Liard Valley all the way upstream to Watson Lake includes considerable areas of promising land for these purposes. Most of the land is light and sandy, but precipitation appears to be adequate for fair growth. Winters are reported to be severe and the gardens at Lower Post were not very promising.

At the Fort Nelson end of the road, good gardens have been raised near the Post for many years, and extensive areas of agricultural land occur in the vicinity. By proper land selection and drainage, small farming may be carried on locally as far west as mile 50, but through the high foothills and mountains soil and climatic conditions are rarely suitable for gardening or farming. Near the junction of MacDonald Creek and Racing River, and again along Trout River below Muncho Lake, horses have been wintered for many years, probably since the gold rush of 1898. Small gardens might be developed in these localities.

Several areas of good land at mile 213, near the hot springs, Liard River, were worked as a garden by Tom Smith and others, and considerable hay was cut off the neglected area in 1943. The region of the hot springs has been called the Tropical Valley by feature newspaper writers in the past, and while "Tropical" does not apply, "Garden Valley" might be used in truth. The forest growth of white spruce, black poplar, birch, and white poplar is especially heavy at this point, but is attributable to low altitude (about 1,300 feet), good soil, and suitable rainfall rather than to the temperature of the springs. There is some very local reaction on the part of plant life to the mineral content of the spring water.

Forests

Sawmills have been operated at various places along the Highway, to supply lumber for buildings and culverts. At mile 10, white spruce was cut that averaged 14 inches on the stump. This timber is about typical of that east of the mountains. In Liard Valley, spruce and black poplar grow to 2 feet at the base, with heights of 100 feet or more. There are stands of fair-sized white birch and some small larch in the low lands and some fair jack pine on the gravelly plains and ridges, especially west of Smith River. The buildings of the Smith Valley Air Port are constructed of jack pine squared on three sides. Firewood is available everywhere. So far loss of forests by fire has been moderate, but the risk remains to be faced during dry periods.

Scenery, Fur, Fish, and Game

The route from Fort Nelson to Watson Lake traverses a land made alluring by fur trader, gold seeker, and a very few hardy explorers. In 1887 Dawson and McConnell entered Liard Valley by Dease River, Dawson going north to Watson Lake and into the Yukon, and McConnell surveying Liard River to the Mackenzie. Many Yukoners made their way to the Klondike along this route and their old trail has remained in use ever since, and for the most part has controlled the route of the Highway.

Major G. B. Hart of Williams Lake spent some 3 years in this region, mapping much of it single handed, for the province of British Columbia.

Tom Smith and his young daughter Jane made a comfortable home for themselves at the hot springs on Liard River, and from there set out on their ill-fated voyage, rafting the Liard toward Fort Liard. Devils Canyon claimed Tom's life and Jane was rescued from an island, where she had made land, by the aid of Indians. Trappers have carried on their hardy calling in the mountain valleys, taking 6 weeks by pack train to transport their furs from Liard River to Fort St. John.

The airplane changed all this, and pre-war landing fields established at Fort Nelson and Watson Lake superseded the landings for hydroplanes on nearby waters. The Highway has provided an easy supply route for the landing fields. The Yukon Trail has been converted into a trunk road to Alaska.

Summit Pass, with its two emerald green lakelets, is a miniature of Jasper. The mile of rock cut on its western side provides a magnificent view of the upper valley of MacDonald Creek. Charlie MacDonald himself, the patriarch of the Grand Lake Indians, may be met in these parts as one of his cabins is not far away.

Toad River gorge provides fine mountain scenery, and Muncho Lake is as picturesque a body of mountain water as could be desired. The 4 miles of rock cut along its eastern side provides a winding drive of great beauty, the emerald lake water and the red conglomerate of the west shore forming a natural harmony. The descent along Trout River is an enticing valley drive and the suspension bridge crossing the Liard furnishes superb views up and down this mighty waterway, which forms the northern boundary of the Rocky Mountains.

Westward the beautiful wooded valley of the Liard is followed by a broad road with gentle horizontal and vertical curves, past Smith, Coal, and Hyland Rivers to Lower Post, where Sylvester's old cabin may still be seen. Northward the road passes into the Yukon along a canyon in Liard River, and a short distance beyond a sign-board at the road forks points north to Watson Lake and westward to Whitehorse and Fairbanks.

The Alaska Highway has fulfilled the dream of generations, an easy overland route to northwestern America and eventually to northeastern Asia.

Northern British Columbia, and especially the Cassiar region, has been looked upon as a hunter's paradise. It happens that the route followed by the Alaska road is not especially rich in game, but the famous Tuchodi Lake is only some 40 miles south of the Highway at the Summit and other good game areas are to be found at the headwaters of Toad River and elsewhere.

Black bear are common and visit most garbage dumps in some numbers. Grizzly bear were seen south of Muncho Lake. Moose and cariboo were scarce and few signs were observed. Mule deer occur as far north as Liard River. At least one flock of Stone Mountain sheep pasture in the vicinity of Muncho Lake. Wolf tracks are common on all trails.

The most northerly herd of wapiti (elk) is resident in the vicinity of Tuchodi Lake.

The streams and rivers of the area have some grayling and whitefish in them, and Muncho Lake is reported to have trout up to 40 pounds weight in its cold deep waters. In general fish are not very plentiful.

The noise of road building, including roar of machinery and blasting, has obviously driven wild life back from the Highway. With the quieter conditions of post construction days, wild animals will doubtless return, especially if protected by a series of reserves or parks. The black bears have certainly responded to protective treatment, and have become as interesting as at Banff or Jasper.

GENERAL GEOLOGY AND PHYSIOGRAPHY

Between Fort Nelson and Watson Lake the Alaska Highway lies almost entirely within northern British Columbia (See map) and traverses five physiographic provinces, each the expression of special stratigraphic or structural features. From east to west these provinces are as follows:

(1) An eastern or plains province extending westerly from Fort Nelson for about 57 miles, and underlain by nearly flat-lying, soft, sandy shales of Lower Cretaceous age.

(2) The Foothills belt, about 50 miles wide, consisting of a deeply dissected Tertiary peneplain; the foothills are underlain by little disturbed Cretaceous shales and sandstones in the east, and by faulted and folded Mesozoic and Palaeozoic formations in the west.

(3) The Rocky Mountain section, as traversed diagonally by the Highway, is about 110 miles long and extends to Liard River. The mountains of this belt rarely reach 8,000 feet above sea-level, but are similar to the more southerly Rocky Mountains in structure and rock components. The geological section comprises thick formations of Precambrian and Palaeozoic age.

(4) Westerly for 20 miles, along the north side of Liard River, the Highway crosses truncated ridges extending northward from the Rocky Mountains. These are separated by extensive valleys. This physiographic province terminates approximately at Smith River.

(5) The last province traversed extends from Smith River for 120 miles to Watson Lake in Yukon, and is a rolling plateau deeply covered with sand and gravel, and varied by low, rounded hills and deep stream valleys.

The last two provinces mentioned are underlain by Palaeozoic rocks that here and there form the foundation for Tertiary lake and swamp, clay and lignite deposits.

The Eastern Plains

For about 57 miles west from Fort Nelson the Alaska Highway traverses a gently undulating plain, below which Muskwa River and its tributaries have carved valleys 200 to 400 feet deep. The plain varies in elevation from about 1,800 feet in the west to about 1,500 feet in the east. The Kledo branch of the Muskwa has a wide, flaring valley, whereas Muskwa Valley itself is deep with steep sides. Near its mouth the river is nearly 400 feet below the adjoining upland. Fort Nelson River Valley at this locality is broad and well graded.

Rock outcrops are few in the plains section. Along the small stream that crosses the Highway through the R. Melville Smith Construction Camp at mile 8[1], dark sandy shales outcrop for 200 to 300 feet to the flat top of a small hill. These shales are flat-lying and contain small concretions. A well was drilled for water just east of the creek, to a depth (when visited) of 208 feet, and black shale continued to that depth. No water was found, and porous, sandy members were not encountered. Nineteen miles farther west, at mile 27, black shale is exposed in a road cut. At mile 50 nearly flat-lying black shale is exposed in the eastern flanks of the hills along the western side of Kledo River Valley. These are described under the Foothills province. To the south of mile 39, a large shale bank may be seen flanking Muskwa River. Available evidence indicates that the eastern plains are underlain by nearly flat-lying sandy shales or shaly sandstones of Lower Cretaceous age. An examination of the valley of Muskwa

[1] Mileages, unless otherwise mentioned, are measured west from zero, the junction of the Highway from the south with the east-west road from Muskwa and the Fort Nelson Air Port, 7 miles west of Fort Nelson.

River will shed further light on the geological section.

The superficial deposits of the eastern plains are sand and shallow muskeg. For 57 miles west of Fort Nelson gravel is lacking, and sand and silt are dominant except where overlain by shallow muskeg swamps. The peat and muskeg conditions are not deep, however, and exist only because of the flat nature of the uplands and the long seasonal periods during which frost prevails in the ground.

The Foothills Belt

On the west side of the valley of Kledo River, near mile 50, the Alaska Highway enters the Foothills belt, which extends westerly to the front of the Rocky Mountains at mile 101.

Westward from mile 50, the Highway rises between nearly flat-lying sandstone and shale hills. Beyond mile 52 the dip is westerly, but the direction is reversed near mile 60 (old road) in a number of prominent flat-topped hills. Of these, Steamboat Mountain, with its overhanging cliff on the east side, is most prominent. Its plateau summit has an elevation of about 4,800 feet, and is a remnant of a former land surface. Other similar remnants are preserved in Table Mountain to the north, Teepee Mountain to the east, and hills to the southeast, as for instance at mile 8, and between the valleys of Muskwa and Prophet Rivers.

The range of hills represented by Steamboat and Table Mountains borders the eastern side of the wide and extensive valley of Mill Creek, which crosses the Highway near mile 67. To the westward the Highway crosses sand and shallow muskeg and approaches Tetsa River at mile 85. At mile 77 slumping sandstone is exposed in the road cut.

At mile 85½ black, coaly shale is exposed in the road cut and a fault separates shale segments that dip respectively 66 degrees east by north and 77 degrees west by south. Near mile 86, flat-lying beds contain Cardium, and near mile 86½ hard siltstone dips 35 degrees to the west. Near mile 87 dark shale dips to the south by east at 23 degrees, and at mile 87½ hard, coarse sandstone dips easterly at 60 degrees. This marks the eastern flank of a prominent anticline with its western flank near mile 89. The axis is only slightly west of mile 88 and its strike is approximately south 30 degrees east. The anticline is clearly defined south of Tetsa River in the form of a hogsback ridge, conveniently sectioned at intervals by erosion channels. On the west flank vertical beds occur, and the geology both on the east and west flanks suggests crumpling and faulting. The rocks exposed on the anticline are of Triassic age.

Near mile 89½ sandstone beds contain Ostrea and black crumpled shale outcrops to the south of the forks of Tetsa River.

At mile 91, vertical quartzite and limestone are exposed in a road cut, the latter containing a rich Productus fauna. The outcrops mark the southern end of a range of hills that include, between mile 91½ and mile 92, sandstone and limestone beds of Mississippian and (?) later age overlain by a series of black chert beds that are probably of Pennsylvanian or Permian age. This belt of Upper Palaeozoic formations strikes approximately south 30 degrees east. It is evidently a block thrust up from the west over and against the Triassic beds to the east. On its western side this block is faulted and its bedding planes are disturbed and quite unrelated to the structure of the overlying Triassic beds.

Hills to the north of mile 93 and mile 94 are crowned by black limestones and limy sandstones of upper Middle Triassic age. The beds have dominant westerly dips varying from 30 to 68 degrees. They represent the east limb of a syncline the west limb of which may be seen north of mile posts 97 and 98, where Triassic shales and dark sandy limestones dip easterly at angles of from 13 to 48 degrees. The structure is locally confused by crushing, as indicated by vertical and reversed dips.

The belt of low rounded hills between the Triassic outcrops at mile 98 and the front of the Rocky Mountains near mile 101 is underlain by black shale, with a general northeasterly dip of 40 to 50 degrees. Crumpling occurs locally, accompanied by reversed dips. The shale is soft in general, but contains some hard chert and quartzose beds. No fossils have been found at this locality, but the shale is probably a lower division of the Triassic sedimentary succession.

The Rocky Mountains.

The front of the Rocky Mountains is sharply defined about one-third mile east of mile post 101. Here, on the upper waters of Tetsa River, grey limestone is faulted against black shale of the Triassic belt just described. The fault strikes west 25 degrees north and dips 75 degrees southwest. The adjoining limestone exhibits a sharply overturned anticlinal structure that is evidently a part of the major anticline that forms the front of the Rocky Mountains for many miles north and south of the Highway. To the north, the axis direction is about 19 degrees west of north, and to the south 23 degrees east of south. As seen from mountain peaks the line between the limestone mountains and the shale foothills is straight and clearly defined for miles to the northwest and southeast. The major overthrust of the mountains has defined the mountain front, but a subsidiary faulted anticline trends obliquely to the strike of the main folding and so extends out into the Foothills, where it may be traced for several miles to the southeast.

The front range of the Rocky Mountains extends westward for 9 miles (to mile 110) as traversed by the Highway. The summit lies between two summit lakes at an elevation of about 4,100 feet above sea-level. The slope on the Highway to the east is gentle, but the switch back between miles 106 and 107, on the west slope, is so steep that a cut 1 mile long has been made in the mountain side between miles 105.5 and 106.5 to give a better grade.

The grey limestone mountains of the pass are similar in appearance to those at Jasper, but the valley itself is much narrower. Peaks to the north and south rise to heights of about 7,000 feet. A main peak to the north is named "St. Paul" on the map and its companion on the south "St. George". Other peaks are nameless. About 15 to 20 miles south by east from the Highway, a group of peaks rises to conspicuous heights, and one of the mountains supports a hanging glacier. This is the highest group seen in the front range, some of the peaks probably rising to 9,000 feet above sea-level.

Along the pass the peaks have rounded crests and are joined by long, gentle ridges. A peak south of mile 105 has conspicuous cirques on its west and north sides, and a terminal moraine occurs where the west facing glacier joined the ice-stream feeding north into MacDonald Creek Valley.

Pronounced terraces of glacial till flank the sides of the pass to an elevation of about 700 feet above Summit Lake. These terraces may be traced for some miles to the east along Tetsa River and for some 20 miles to the northwest down MacDonald Creek. North of Summit Lake, local erosion has left well-developed "hoodoos" of till standing on the mountain side. Similar terraces occur along Muncho Lake and up a side valley hoodoos are present, and others are being formed.

In the bottom of MacDonald Creek and in the westerly facing cirque mentioned above, quartzite and slate rock of grey to reddish colour forms the basal formation upon which the limestone mountains rest. These metamorphic rocks dip at high angles, and on their bevelled edges, and at various elevations, rest grey limestones of coral reef origin. The corals are Middle Silurian in age, Halysites catenulatus being most easily determined among the silicified forms. Upwards from this unconformable base, rise 2,000 to 3,000 feet of light grey limestone with at least one massive member of hard grey sandstone nearly 70 feet thick. The upper limestone members appear in general to be unfossiliferous. On the western side of the front range, however, near mile 109, black shale overlies grey coral reef limestone as seen in the falls of a mountain stream. Corals and a trilobite pygidia represent a Middle Devonian age for these beds. No boundary has been found between the Silurian and Devonian members of this limestone series.

Overlying the Middle Devonian limestones of the Rocky Mountain belt are fissile black shales. At the contact near mile 109 mentioned above, these shales are rusty weathering and are full of Tentaculites spiculus Hall (?). Two feet above the contact a poorly preserved Meristella ? was found. Thus the lower beds of the black shale formation may be Upper Devonian, possibly Chemung, in age.

Farther to the northwest, down the valley of MacDonald Creek, the bordering hills are low and wooded and rock formations consist of black shale, argillite, black chert, and dark-coloured sandstone. These soft weathering rocks are dominant to the junction with Racing River and overlie limestone westward up Toad Valley as far as mile 143. In general these shales are unfossiliferous, but in the hills to the east of mile 116 poorly preserved fossils probably represent Michelinia, and the following genera are recognized: Productella, Martinia, Athyris, and Euomphalus. The general impression conveyed is that of a Mississippian age, and the shales strongly resemble the Banff shales of the Rocky Mountains farther south. As already described, the shales weather easily and are eroded into rounded hills and valleys. They will be referred to again as occurring along Trout and Liard Rivers.

Mountains formed of Silurian and Devonian limestones appear here and there from Racing River westward, rising through their overburden of dark Devono-Mississippian shales. From mile 143 westward up the narrow valley of Toad River, such limestone peaks are dominant. Between miles 152 and 158, however, older quartzites and slates show here and there in the flanks of the mountains, and form the peaks south of Toad River from mile 154 to 159. Along the Toad these metamorphic formations are steeply folded and are cut by irregular basic intrusions and a series of vertical dykes averaging about 50 feet in thickness. An unconformable relationship with overlying Middle Silurian coralline limestone is clearly seen in the valley wall. The metamorphic rocks are presumed to be of Late Precambrian, Proterozoic age. The mountains south of the Toad, and those flanking its upper valley, are high and of formidable aspect.

At mile 159 the Highway turns nearly due north and follows a large valley occupied in the south by the upper waters and lake expansions of Toad River and to the north by a small stream flowing into Muncho Lake. Northward, Muncho Lake extends for some 10 miles and is drained by Trout River through a continuation of the same mature valley, which takes a northwest by north course to join the trunk, east-west valley of Liard River. The northerly trending valley, thus delineated, is practically on the prevailing strike of the mountain structure. The Highway follows it for 50 miles, and, as previously stated, the valley extends for an undetermined distance southward to the headwaters of Toad River. It is quite apparent that the valley of Toad River for 30 miles above its junction with Racing River represents a relatively recent diversion of the stream from its earlier course northward through the Muncho Lake-Trout River system.

Along Muncho Lake-Trout River Valley the mountains to the east rise as limestone peaks of considerable height. One of the most prominent, not shown on the map, lies 3 miles east of mile 164 and reaches an elevation of about 7,600 feet. In the valley walls and in small tributary streams the underlying Cambrian (?) quartzites and sandstones are exposed at various places. Along the western side of Muncho Lake the general formational dip is to the southeast and formations underlying Middle Silurian coral reef formations are exposed about 3 miles north of the head of the lake. The upper beds are sandstone, but beneath these is a thick red conglomerate that extends northward beyond Muncho Lake to mile $197\frac{1}{2}$. Within the area of the conglomerate formation are several high mountains not yet investigated, including one marked on the map as 8,300 feet in elevation.

From mile $197\frac{1}{2}$ to mile 202 the valley is in Siluro-Devonian limestone. Northward of this point, very soft, black to dark grey or brown shale outcrops at intervals into the valley of Liard River, where the Rocky Mountain province ends. The northern Rocky Mountains are flat-topped or elevated ridges of limestone rising 6,000 feet or more above sea-level. Their rather abrupt termination at Liard River is probably due to differential regional uplift, for the general formational dip is south, not north as might have been expected. Some local east-west faulting has been observed, and this was probably a phase of the differential uplift.

Liard Valley, Trout River (Mile 210) to Smith River (Mile 230)

Westward from the crossing of Liard River, near the mouth of Trout River, the Highway follows the northern bench of the Liard. This consists of glacial silt and river deposits and supports an unusually heavy growth of northern timber. The abandoned gardens, formerly worked by the ill-fated trapper Tom Smith, are situated at mile 213, and the hot springs, for which the region is famous, are situated across a beaver pond a few hundred yards to the northwest. This is, in fact, the so-called "Tropical Valley". The character of the springs will be discussed elsewhere in this report. They are in keeping with local evidence of rock disturbances. East of the springs a prominent ridge of sandstone and shale rises to an elevation of about 3,200 feet above sea-level. Other, north-south ridges of shale occur westward to mile 221. No fossils were found in any of these outcrops, but at mile 213, near the northern footing of the suspension bridge across Liard River, hard, black, interbedded limestone has furnished fossils representative of Mississippian time. The shales along this stretch of the Highway are thus correlative with those of the Banff formation.

Westward to Smith River (mile 231) the road passes the south end of limestone ridges that extend for some distance northward. These rise in places to 3,600 feet and carry reef corals of Middle Silurian age.

Black to rusty shale outcrops east of Smith River in a road cut and similar shale occurs about $1\frac{1}{2}$ miles up the river at a 50-foot falls, where it is downfaulted against grey limestone.

Just west of Smith River a road branches north and continues 25 miles to Smith River emergency landing field. Four miles north of the forks grey limestone is exposed in a road cut. Farther north the road traverses bench lands of gravelly and sandy nature, generally lightly forested with jack pine and white poplar. The plain has an average elevation of about 2,200 to 2,300 feet and is typical of the area west of the northerly extending ranges that replace the mighty Rocky Mountains of the south. These ranges are seen to the east as smooth, even-topped ridges.

Liard Valley, Smith River to Watson Lake

Westward from Smith River, the Highway follows the Liard River bench and is nowhere far from the stream. The country to the north is gently rolling, and is in general well forested. The land is sandy, but extensive gravel deposits underlie the sand. The country south of Liard River is similar to that on the north, but in general appears more dissected by streams.

Four outcrops of limestone were observed along the Highway between Smith and Coal Rivers (mile 250); limestone also outcrops on the river at the canyon south of mile 249 and in the west bank of Coal River above the bridge. These beds have a general northwesterly strike and the direction of dip varies so as to suggest a series of sharp anticlines and synclines.

Coal River derives its name from the large masses of brown lignite that drift onto the bars near its mouth. McConnell walked up the river for some distance without finding the source of the coal. The writer and J. DeLeen discovered the coal in situ north of the big bend in the river and probably not more than 6 miles from the Highway "as the crow flies". By water the distance is much greater.

The lignite outcrops across the river bed forming a rapid. Fifteen feet of coal is exposed in the west bank, dipping to the southwest at 25 degrees. The seam is covered by clay and gravel and the foot-wall is not visible. A few hundred yards upstream the seam is actively on fire. Steam and foul-smelling gases are being given off, tar is melted at the surface, sand and gravel are caving in, and trees and bushes show all stages of destruction. The area on fire is small, however, and is separated from the main seam by a burnt out zone. It is clear that there is here a Tertiary basin of considerable extent. Local reports lead to the belief that the coal extends several miles upstream to a falls in the river.

Below the big bend in Coal River, and about 2½ miles from the Highway bridge, white clay rises in the west bank for 15 feet and extends for 100 yards along the stream, and lower downstream is another outcrop, 100 yards long. The white clay evidently belongs in the same Tertiary basin as the lignite.

Westward from Coal River, grey-blue sandstone outcrops along the Liard at mile 261, and sheared shale in road cuts at mile 264 and from mile 267½ to mile 268. Dips are generally high and strikes variable.

Grey limestone outcrops from mile 270 to mile 271. Shale outcrops at mile 277 and fractured limestone at mile 280. Limy sandstone outcrops at mile 281 and limestone at miles 285 and 286¾, in hills south and north of mile 288, and at miles 291 and 292. Outcrops of shale occur at miles 305, 306, and 309.

Banded dark shale occurs near mile 316 and crushed black shale in numerous outcrops from mile 319 to mile 321.

About a mile up Dease River, which enters the Liard half a mile below Lower Post, dark shale occurs on the right bank of the river, and black shale overlying chert conglomerate forms a dangerous 2-mile rapids. At the time visited, the small paddle-wheel steamer Dease River, S.W. 1 lay a wreck on a rock in the middle of the rapids. The formation here dips about 70 degrees to the northwest.

Northward along the Highway beyond mile 342, and near the British Columbia-Yukon boundary, black and rusty shale outcrops in Liard River forming a canyon, and very soft weathering shale and interbedded limestone outcrop for about 800 yards along the road. The dip here is about 28 degrees toward the southwest.

Northward, the Highway is some distance east of the river and traverses a rolling sandy terrain that is part of the river valley. At mile 350 a branch road turns north to Watson Lake Air Port.

Watson Lake is about 5½ miles long and 1½ miles wide. Its elevation is shown as 2,230 feet above sea-level, and the adjoining plain rises about 10 to 15 feet above it. Only sand was noted in the banks of the lake. Low, wooded hills appear 10 to 12 miles to the northeast.

Old Land Forms

The composite skyline of the Rocky Mountains is somewhat above 7,000 feet in the front ranges near Summit Lake and somewhat below 6,000 feet south of Liard River. Individual peaks and groups of peaks rise above the general level, where structure and rock hardness have resisted erosion. Elsewhere greater initial uplift may have been a controlling factor. Softer rock formations have been eroded into lower mountain groups or into valleys.

Extending outward from the mountains, especially toward the east, remnants of a plains surface are preserved in numerous flat-topped hills. This surface is tangent to the upper rounded mountain tops of the Rocky Mountains and dips away with decreasing slope approaching the horizontal 50 miles from the mountains. The perfection of upland preservation is dependent upon relation to stream channels, but more especially upon the structure and resistance of the underlying rocks. Thus at mile 98, 1½ miles from the Rocky Mountain front, folded Triassic sedimentary beds of little resistance to erosion form rounded hills with an elevation of about 5,400 feet. Near mile 94, similar formations rise to 5,000 feet. Thirty miles farther east the resistant conglomerates of Steamboat, Table, and Teepee Mountains rise to a maximum elevation of 4,800 feet, with surface slopes representing the attitude of the beds. From these upland surfaces, flat-topped hills are conspicuous to the southeast and to some extent to the east and northeast.

Westward from the front range of the Rocky Mountains, the upland surface sags into the valleys of MacDonald Creek and Racing River, where rounded, forested mountains of little resistant, shaly rock have preserved the former upland very imperfectly. The Rocky Mountains south of Liard River preserve occasional level tops, and the isolated mountain ridges and hills north of the Liard indicate the general downward slope of the upland in that direction. From a summit elevation of about 3,000 feet near Liard River, the uplands drop to about 2,000 feet farther to the north.

Well-defined benches are preserved on resistant sandstones on Steamboat Mountain and nearby hills at elevations of 400 to 500 feet below the upland surfaces. Such benches may be traced to the westward where low flat-topped hills, or valley bottoms, now deeply entrenched, represent once widespread and well-established lowlands. These lower surfaces are represented in the Rocky Mountains themselves north of Summit Pass, where rocky terraces occur at an elevation of about 5,000 feet. From the pass, the benches descend to the west down the valley of MacDonald Creek, where they lie only poorly preserved in the area of Devono-Mississippian shaly rocks. Northward from Toad Valley are similar benches but with the general northward decline of the upland surface and the widespread effects of glaciation the lowland benches for the most part lose their identity.

The valley system of the region is deeply entrenched below the old land surfaces. The pre-glacial valleys were deeper and probably better graded than those of the present system, although the immediate pre-glacial uplift resulted in rapid down-cutting and stream adjustment. An excellent example may be seen in the Toad River-Muncho Lake-Trout River systems. The upper, laked valley of Toad River is continuous with the valley now followed northward from mile 159 to Liard River. Except for a short tributary of the Toad, the valley is occupied by the Muncho Lake-Trout River drainage, and is wide and of mature development. From the bend of the Toad at mile 159, the river descends through a canyon of youthful character for 10 miles to the east before entering the wide, mature valley of Racing River. The canyon was filled with till and ill-sorted gravel, and is clearly pre-glacial, but it was evidently developed during the period of maximum uplift and consequent drainage adjustment immediately preceding Pleistocene time.

The Ice Age itself modified, rather than developed, the drainage system. Widened valleys, scarped spurs, hanging valleys, cirque formation, arrêtes, and other typical glacial forms resulted.

The continental ice-sheet extended into the Foothills valleys almost to the mountain front, damming back the mountain glaciers with their loads of boulders, gravel, sand, and rock flour. The continental sheet retreated first, for remnants of mountain glaciers still remain south of the pass. At the close of the Ice Age, the whole land was probably 600 to 700 feet lower than at present and the valleys were clogged with morainal and glaciofluviatile material to that depth. With the passing of the ice, the land gradually rose and re-excavation of valleys started. That process is still continuing rapidly, but at few places is the solid rock being attacked by stream erosion, as glacial debris covers most of the valley floors. Mountain streams are cutting gorges, and falls occur where they enter the main valleys. Gorges and rapids occur in rivers where new channels have crossed rock spurs in old valleys, but in general post-glacial erosion is closely controlled by the established pattern.

The unstable (youthful) condition of the present stream system was amply demonstrated during the floods of 1943, to which reference has been made. Besides mud slides, erosion of river bars and river banks and widespread destruction of road grades and culverts, rock slides occurred such as are described below.

Near mile 94, the pioneer road location crossed a small stream valley some distance up the hillside. The road grade descends in both directions from the culvert. For 100 yards or more the stream bed is in angular slide rock from the hill to the north, but this is covered with small timber. During the flood of July 10 the stream overflowed its banks, loosened a large quantity of coarse rocks and piled it up 6 feet high across the roadway, covering some 50 yards of road. Blocks 2 feet across were thus moved. A remarkable feature of the slide is that the base of the rock pile is above the level of the stream and higher than the source of much of the material.

Mountain Building and Crustal Movements

The structure of the Northern Rocky Mountains is similar to that of the system farther south. Compression from the west resulted in overturned folds and thrust faulting toward the east along the mountain front. The time was Laramide, that is late Cretaceous and early Tertiary. Lower Cretaceous formations were intimately folded.

Post-Cretaceous uplift is recorded in minor folds in Upper Cretaceous formations of the Foothills and in uplifted and tilted plateaus underlain by Upper Cretaceous beds. This uplift was followed by the development of a peneplain that matches similar plains farther south. By analogy, the uplift may be assigned to Eocene time and the peneplanation to Miocene time.

Another uplift followed, probably early in Pliocene time, and broad lowlands and flaring valleys were developed 400 to 500 feet below the peneplained surface. Late Pliocene uplift initiated the deep dissection of plains and mountains, which increased in tempo until the ice cover grew to glacial proportions and the Ice Age had begun.

DESCRIPTIONS OF FORMATIONS

Table of Formations

Age	Character	Thickness Feet
Recent	Sands, gravels	100 ±
Pleistocene	Till, gravel, and sand	up to 500
Tertiary	Clay, lignite	200 ±
Upper Cretaceous	Conglomerate and sandstone	600 +
	Shale and sandstone	1,500 +
Lower Cretaceous	Siltstone, sandstone, and lignitic shale	500 +
Triassic	Black argillaceous limestones and sandstones	2,000 +
Pennsylvanian or Permian	Black chert	300 +
Mississippian and (?) Later	Limestone and calcareous sandstone	400 +
Devonian and Mississippian	Black argillaceous limestones, dark shales and sandstones	2,500 ±
Silurian and Devonian	Limestone and interbedded sandstone	4,000 ±

Age	Character	Thickness Feet
Pre-Middle Silurian (Cambrian?)	Grey sandstone and red conglomerate	5,000 +
Precambrian	Dolomite, slate, and quartzite, cut by basic dykes	2,000 +

Precambrian

The oldest formation traversed includes the most highly metamorphosed strata of the region, and is the only formation known to be cut by intrusive rocks. It is best developed along Toad River, but is well exposed also along MacDonald Creek. Whole mountain groups composed of these rocks are yet to be explored in the headwaters of MacDonald Creek, up Toad River southwest of the Highway, and probably west of Muncho Lake north of Gundahoo Pass.

In the type section on Toad River, near the Highway crossing, highly folded, light-coloured quartzite and porcellanous argillite and slaty rocks rise 600 to 1,000 feet from the valley floor and are overlain by nearly flat-lying grey limestone containing reef corals of Middle Silurian age. The contact is everywhere marked by an angular unconformity. Mud-cracks and ripple-marks are well defined in the argillites, which are generally limy and locally contain small mud balls. The cleavage in the limy beds is in most places parallel to the bedding. Some of the beds, however, consist of bands of quartzite and grey slate, and in these the cleavage is independent of the bedding planes. Colours vary from light yellow or green to dark grey, and the formation generally weathers dark brown.

The ripples on the quartzite are well marked. At one locality ripple-marks of ½ inch amplitude are overlain by current ripples 1½ inches in amplitude. The variability of the sediments and their mud-cracks and ripple-marks indicate near-shore conditions in a seaway that was receiving sediments from a fluctuating source of supply.

About 300 yards southeast of the bridge over Racing River an irregular diabase dyke cuts light-coloured quartzite and porcellanous argillite. The dyke averages about 15 feet in width and is apparently vertical. The dyke rock is hackly fractured and is cut by quartz stringers.

North of Toad River and the Highway, between miles 156 and 157½, five 50-foot vertical dykes cut the quartzites and associated rocks and extend upward to the top of the formation, or to an elevation about 1,000 feet above the valley. These dykes were studied in the field and examined under the microscope by J. DeLeen who reports as follows:

"Two thin sections were examined; they are from a dyke 50 feet wide in fine-grained grey limestone. One section from the centre of the dyke shows a maximum grain length of 1 millimetre. About 50 per cent of the rock is plagioclase (Ab_4An_6) that is now largely altered to carbonate. About 30 per cent of the rock is hornblende that is partly converted to chlorite, and there is not over 2 per cent quartz, about half of it intergrown with feldspar as micropegmatite. Disseminated grains of magnetite and pyrrhotite, in about equal amounts, constitute nearly 15 per cent of the rock. A few shreds of actinolite and flakes of biotite complete the mineral assemblage.

"Another section, from the edge of the dyke, shows the grain size reduced to a maximum of $\frac{1}{2}$ millimetre, and is of interest in that augite is present in amount about equal to that of hornblende in the first slide and hornblende is absent. The augite is in part converted to pale green chlorite and, to a very minor extent, to biotite. Plagioclase of the same composition as that in the first slide is almost entirely replaced by carbonate, which also occurs in a few microscopic veinlets. Quartz, magnetite, and pyrrhotite are present in the same amount as in the centre of the dyke and there are a few scattered grains of epidote.

"The rock is a fairly typical quartz gabbro, moderately altered to chlorite and carbonate. The interior portion shows the development of hornblende at expense of augite that leads some authorities to apply the name hornblende gabbro or gabbrodiorite. In the field such dykes, and particularly the finer grained phases, are generally termed diabase, though the characteristic ophitic texture of true diabase is lacking in this case."

The Precambrian quartzites are also well exposed $1\frac{1}{2}$ miles up MacDonald Creek, south of the rock-cut at mile $106\frac{1}{2}$. Here vertical beds of quartzite underlie disturbed Middle Silurian coral reef limestones. The quartzites are jointed and sheeted, and are cut by a number of quartz veins showing brown and yellow stains. In a cirque on a mountain to the east of the creek, rusty quartzite unconformably underlies nearly horizontal Silurian limestone. The quartzite is slaty in part, is very dark when fresh, but weathers rusty. A 300-foot section of quartzite is here exposed.

From the river flats large quartzite mountains may be seen to the south.

Cambrian (?)

In the west bank of Muncho Lake, about 3 miles north of its head, Silurian coral-reef limestone is underlain by about 50 feet of limy shale that is full of worm burrows. Underlying the shale to the north, and with comparable strike and dip, are outcrops of grey sandstone in beds 8 to 10 feet thick. Other sandstone outcrops to the north indicate a thickness of more than 2,000 feet of these beds. About $2\frac{1}{4}$ miles north of the highest sandstone outcrops, coarse red conglomerate is exposed on the shore, and from here northward it forms almost continuous cliffs and hills along Muncho Lake and the west side of Trout River valley to mile 197.

Assuming the entire section to be sandstone from the base of the limestone series to the top of the conglomerate as exposed on the shore, and assuming no great variation from observed dips, and no serious faulting, the sandstone would have a thickness of nearly 5,000 feet.

The conglomerate near the top is massive and contains boulders of pink quartzite up to 10 inches in diameter. Fifty yards north the conglomerate consists of a fine red shale matrix with pebbles 6 inches and less in diameter. The great lineal extent of the conglomerate formation to the north is suggestive of great thickness, as is also suggested by the massive mountains to the west of Trout River where a peak is mapped with the elevation of 8,300 feet. Until this region is studied in some detail the thickness of the conglomerate formation cannot be safely estimated.

For 10 miles south of Muncho Lake, in streams entering the lake from the east, and for 17 miles north of the lake along Trout River, porcellanous shale, sandstone, and conglomerate are overlain by coral reef limestone of Middle Silurian age. In many cases the outcrops are too small to map. Near the limestone contact are shales full of worm burrows, and south of Muncho Lake some of the sandstones are limy and contain fossils.

Near the contact, most of the clastic rocks approximate the limestone in structural relations, but lower beds are quartzitic, and resemble the Precambrian sediments in metamorphism and complexity of structure. Near Toad River there is much uncertainty as to the identity of the beds, but farther north they appear to belong to the upper division of the Cambrian (?) series, as represented along the west side of Muncho Lake.

Along Trout River Valley the limestones dip westerly for several miles north of Muncho Lake, and faulting along Trout River has probably been responsible for their relationship with the Cambrian (?) sediments, which rose as mountains west of the river. Such faulting is known to have occurred commonly in the nearby mountains.

The age of this sandstone-conglomerate group is pre-Middle Silurian, as wherever observed the upper sandstone member is overlain by a few feet of worm-burrowed shales and their closely associated overlying coral reef limestone. What the actual age of these clastic deposits is can only be conjectured from lithological comparisons. Known Ordovician beds on Dease River consist of graptolite-bearing shales, but Keele (1910) found on Gravel River, in addition to graptolite-bearing shales, 4,000 feet of argillites and dolomites, surmounted by a 100-foot diabase sill and 1,500 feet of sandstone, all of which he places in the Ordovician. To the east the sandstone increases to a thickness of 4,500 feet, the prevailing colour being reddish.

In his Middle or Lower Cambrian, Keele (1910, pages 37 and 38) includes 2,000 feet of conglomerate and 100 feet of coarsely laminated hematitic and siliceous shale.

In the light of available evidence the writer leans towards the conclusion that the conglomerate and overlying sandstone of Muncho Lake and vicinity may be Cambrian. The group bears some similarity in stratigraphic relation and lithology to the Cambrian beds of Gravel River and of Franklin Mountains.

Silurian and Devonian

A thick series of grey limestones with associated basal shales and interbedded sandstones is exposed westward from the front of the Rocky Mountains. Along MacDonald Creek south of the Highway the series rests upon the eroded surface of Precambrian slates and quartzites, and a similar contact relation occurs along Toad River. Along the east side of Muncho Lake-Trout River Valley, and on the west side of Muncho Lake, as already described, the limestone series rests on light-coloured Cambrian (?) sandstone.

The upper contact of the series is conformable with overlying shales of Upper Devonian age, belonging to the next series to be described.

The most complete sections studied occur in the vicinity of the Summit. Although both top and bottom of the section were observed, the intervening structure has not been worked out and the thickness can only be estimated. Also the boundary between Silurian and Devonian members of the series has not been determined.

As seen on the west side of Muncho Lake, about 50 feet of limy shale marked with worm burrows forms the lowest member of the limestone series and is directly overlain by typical coral-reef limestone. The exact contact between the shale and underlying sandstone was not seen, but the strike and dip of the two varied, suggesting an unconformity, as occurs elsewhere.

The lowest limestone member of the series appears to be everywhere of coral-reef origin, and this condition continues or is repeated for hundreds of feet upwards, even above heavy sandstone members of the formation. The corals are typical of mid-Silurian seas. The middle beds of the series consist of light grey limestone that appears to be entirely unfossiliferous. The upper beds consist of grey limestone including coral reefs of Middle Devonian age.

Near the Summit, a composite section may be described as follows. At MacDonald Creek blue limestone is interbedded with quartzite beds up to 10 feet thick and overlies brown weathering, fine-grained quartzite. A 50-foot coral reef occurs in the lower limestone and contains highly silicified corals, among which may be recognized Halysites catenulatus and Eridophyllum rugosum (?). The bedding here is vertical and the rocks are highly silicified.

To the eastward, in the wall of a cirque, coralline limestone unconformably overlies folded, brown weathering Precambrian quartzite. The irregular bevelled contact may be seen clearly in the north wall of the cirque.

A thick limestone section may be studied in Mount St. Paul and adjacent mountains to the west. The lower beds are generally folded and overthrust, but the higher beds have gentle dips. Sandstone beds occur at different elevations. They vary from a few feet to 70 feet in thickness and grade into the limestone at top and bottom. In places the contact is faulted, the sandstone being the more competent bed and overriding the limestone. Middle Silurian corals occur above and below the sandstone. The peak of Mount St. Paul seemed unfossiliferous. The maximum height of these mountains above Summit Lake is about 2,600 feet, giving a minimum thickness for the formation. Neither top nor bottom of the section is seen at this locality.

The top of the limestone section is well exposed in the bed of a small mountain creek that crosses the Highway from the north near mile 109, or 6 miles west of the Summit.

About 200 to 300 feet below the top, the limestone is thin-bedded and mud-cracked into irregular polygons 9 to 18 inches on the sides. The upper limestone is dark grey and includes coral reefs from which the following fossils were obtained: Favosites basaltica Goldfuss(?) and another colonial coral, Conocardium(?), Fenestella(?), Bactrites(?), Atrypa cf. spinosa Hall, Schuchertella(?), Proetus sp., and Conolichas(?). This fauna, dependent as it is upon poorly preserved fossils, nevertheless is varied in species and has Middle Devonian characters. In a general way it suggests Middle Devonian faunas of Mackenzie River.

The limestone is overlain by a thick series of thin-bedded, black shales, carrying hard limy beds a few feet above the contact. These shales appear to be conformable upon the limestone, but are thought to be Upper Devonian in age as described below.

Another fossiliferous horizon in dark grey limestone was found near a temporary bridge over Racing River (former mile 133; the present road crosses 2 miles lower down stream). The following Middle Devonian fossils are recognized: Reticularia modesta (Hall), Meristella sp., Schuchertella sp., Odontocephalus sp., and undetermined corals.

The base of the Devonian limestone has not been determined, and its thickness is not known.

Devonian and Mississippian

A thick series of dark shales occurs over large areas adjoining the Highway west and north of the front range of the Rocky Mountains. The basal beds outcrop near mile 109, as described above. A few inches above the Middle Devonian coral reef limestone, thin beds are packed with tiny fossils that correspond exactly with illustrations of Tentaculites spiculus Hall as found in Chemung shales of New York and Pennsylvania. Two feet above the contact a poor specimen of Meristella? was found. Elsewhere soft black shales are faulted against Siluro-Devonian limestone, or appear to lie above the limestone. Down MacDonald Creek, along Racing River, and particularly in Liard River Valley, dark shales of variable hardness and black limy shale occupy large areas, and weather into valleys or rounded, subdued hills, generally with a brownish cast. Some of the shale weathers into soft mudstone; some outcrops are laminated; some have sandy and limy lenses; and still others are very hard and slaty. A few poorly preserved fossils have been found along MacDonald Creek and in Liard Valley and these suggest a Mississippian age for the containing beds. Uppor Devonian fossils were also found in basal shale beds near mile 109. The general character of the series suggests a correlation with the Minnewanka and Banff formations of the southern Rocky Mountains, the Minnewanka limestone being Upper Devonian and the Banff shales Mississippian.

Dark shales with conglomerate and sandstone beds and sandstone lenses occur at the mouth of Dease River and above and below Lower Post on Liard River. No fossils have been found in these and their inclusion in the Devono-Mississippian series is based upon their assumed position above the Siluro-Devonian limestones and the general similarity of the shales to those of the eastern sections. On the other hand, Dawson found Ordovician graptolites in dark shale about 12 miles up Dease River, and it is possible that the shales from the vicinity of Irons Creek and west are of pre-Devonian age. A critical area extends 18 miles west of Irons Creek. An intensive search for fossils in the shales in this area might provide the necessary evidence.

The best known basal beds of shale, as described above, overlie Middle Devonian coral reef limestone. The contact is sharp and may be disconformable, as a lapse in time is indicated by the fossils contained above and below the contact.

Other exposures of shale are described below, in the order of their occurrence from east to west.

At the front of the mountains, about 500 yards east of mile 101, black, fissile, "pencil" shale stands vertically against the east vertical limb of grey Silurian limestone. The shale weathers rusty yellow, iron sulphate appearing on the surface. It shears in square "pencils" and plates. Eastward of mile 100, black shale of varying character, including hard sandstone beds, passes upward into fossiliferous Triassic sandstone and limy shale. The age of the fissile shale in faulted relation with the front limestones of the mountains remains in doubt. It may be Devonian, as is the case in similar limestone-shale relationships farther west; it may be Triassic, in which case it represents a part, probably a lower division, of the Triassic section succeeding it to the east. This last conclusion is the most likely from a structural point of view, as a Devonian age would involve complicated faulted relations between the "Devonian" and Triassic shales.

Rounded, wooded hills of shale flank MacDonald Creek Valley from mile 110 to mile 125. The shale strikes about northwest by north, and this determines the direction of the valley. The structure is principally that of a syncline with limbs dipping at angles from 35 to 50 degrees. In the northern part of the valley the structure is anticlinal.

In the south flank of MacDonald Creek Valley, between miles 113 and 114, the shale weathers reddish brown to coaly black, and much black iron sulphate occurs on the surface. Here the shale is crumpled into a narrow syncline.

At mile 116, hard, black, cherty rock is exposed in the road-cut, and the mountain to the east is composed of limy sandstone and shale. In these the following fossils were found and have been identified tentatively by A.E. Wilson of the Geological Survey: Productella sp., Martinia sp., Athyris sp., and Euomphalus sp. This assemblage indicates a probable Mississippian age for the beds exposed in the top of the mountain, which is synclinal in structure.

Slaty beds occur at mile 120½ and hard sandstone at miles 122 and 124.

Hills of reddish formations rise west of Racing River. In its eastern bank, at mile 130½, sandstone and shale outcrop in a road-cut. Productus sp. and Martinia? were collected there, representing a Mississippian age for these rocks.

Beyond Middle Devonian limestone in the gorge of Racing River, the Highway crosses alternately shale and dark limestone to mile 143. The shale is very dark, is generally fissile and soft, and represents the lower division of the series. Although no fossils were found in it the close relationships with the dark limestones suggests a Devonian age.

Shales are missing from the Highway to mile 200. At mile 202 in the valley of Trout River hard black shale occurs in the road-cut. At mile 207, very soft hackly mudstone, with soft sandy beds discoloured with iron rust, occurs in a road-cut and in an island in Trout River. The island seems to represent a slumped segment, and the general condition of the shale suggests preglacial weathering.

North of mile 211, on the north side of Liard River, round-topped hills rise to an elevation of about 3,200 feet, or 2,000 feet above the road. These are composed of brown weathering argillite, sandstone, and chert thrown into irregular folds. The argillite is sheared, so as to weather into "pencils" and flakes. No fossils were found on this hill.

On the north side of Liard River, just west of the suspension bridge, very dark grey, calcareous argillite forms a buttress in the river bank. In fresh blasted surfaces, the following fossils were found in a very poor state of preservation: Productus sp., Cliothyridina cf. lata Shimer, cf. Reticularia pseudolineata Hall, Brachythyris? sp., Dielasma sp., Martinia sp., and an unidentified gasteropod. This fauna is Mississippian in age, corresponding rather closely with the Banff shale of the Jasper Park area, or the middle member of the Banff formation of the Banff area, as described by Warren, or the Banff formation of the Moose Mountain-Morley areas as described by Beach. The correlation is with the Kinderhook fauna of Missouri development.

Argillite of similar character occurs in tilted position some 12 miles down Liard River at the head of the canyon at Devils Portage.

West along the Highway to mile 221, a dark argillite hill rises northeast of the road. The rock is hard and weathers rusty.

A rounded argillite hill occupies the angle between Liard River and the creek from Fishing Lakes.

Black, rusty weathering shale outcrops in the road just east of Smith River, and similar shale is down-faulted against massive limestone at the falls about 1½ miles up the river.

At mile 261 grey-blue sandstone occurs along the north bank of Liard River. Fractured and sheared shale occurs near mile 264 and mile 268. Shale also outcrops at mile 277.

West and north of a series of limestone ridges, shales occur in road-cuts at miles 305, 306, and 309. Sandstone beds occur in the last outcrop. At mile 316, soft banded shale occurs in a road-cut and black hackly shale occurs from mile 320 to 321.

West of Hyland River no rock is exposed along the Highway below Lower Post. McConnell reports three outcrops of shale, sandstone, and quartzite in Liard River between these points.

About a mile up Dease River, dark shale occurs in the south bank, and farther up, Two Mile Rapids are formed over black argillite resting on black chert conglomerate.

Black shale outcrops in the canyon of the Liard just south of the British Columbia boundary, and limestone and soft weathered shale outcrop for more than half a mile along the road.

No fossils were found in the shales and associated beds west of the Liard bridge and their age is, therefore, based upon lithology and their relationship to the older limestone series. West of Hyland River, hard sandstone beds and limestones appear in the shale series, and the Siluro-Devonian limestones do not appear. Dawson found Ordovician graptolites in shales about 12 miles southwest of Lower Post, suggesting the possibility that the western shales may underlie the Siluro-Devonian series. The shales along the lower Dease and upper Liard Rivers, however, do not suggest graptolite shales to the writer, and their rather close resemblance to the more easterly outcrops makes it seem desirable to include them tentatively with the Devono-Mississippian series.

The thickness of this series is not known, but it is evidently some 2,000 feet thick at the Liard crossing. Its widespread occurrence suggests that it may be much thicker. As pointed out, Upper Devonian shales make up the base of the series, and Mississippian (Kinderhook) argillites, sandstones, and limestones its higher members.

Mississippian and (?) Later

Mississippian and, possibly, later Palaeozoic shaly sandstones, black shales, and grey limestones, 600 feet or more in thickness, occupy a belt crossing Tetsa River and the Alaska Highway between miles 90 and 94. The eastern half of the section has prevailing vertical dips and the contact of the series is clearly in faulted relation with Triassic beds to the east. Upward, these strata are overlain without apparent break by Pennsylvanian (or Permian) chert beds.

The best section of the "Mississippian" beds is exposed in the valley of a small creek entering Tetsa River near mile 91½. Starting at the bottom of the creek, the section consists of shaly, limy sandstone succeeded upward by fine, argillaceous, limy sandstone containing Productus. These beds effervesce freely with cold hydrochloric acid, but weather into sandy surfaces. Similar beds, alternating with black shale, continue stratigraphically upward for 125 feet from the base of the section, to black chert of the succeeding formation. Near the top are numerous spiriferoids.

In the base of the section the following fossils were found: Productus crawfordsvillensis Weller(?) and Spirifer floydensis Weller. Near the top of the section: Productus inflatus McChesney(?), Productus burlingtonensis Hall, P. crawfordsvillensis Weller(?), P. magnus Meek and Worthen, P. jasperensis Warren, and Spirifer floydensis Weller. At the top of the section and just below the chert beds the following were found: Spirifer floydensis Weller(?) and Syringothyris subcuspidata (Hall)(?).

One-half mile east, near mile 91, highly crinoidal limestone and hard sandstone stand vertically. The limestone contains the following fossils: numerous crinoid columnals, small for the most part, but some ½ inch in diameter; bryozoa, not identified; Productus burlingtonensis Hall, P. crawfordvillensis Weller, P. magnus Meek and Worthen(?), P. inflatus McChesney, Chonetes chesterensis Weller(?), Dielasma sp., and Euomphalus utahensis Hall(?).

To the west, at mile 92, fossiliferous limestone and overlying limy sandstone contain a wealth of fossil brachiopods and pelecypods and some trilobites. A loose block of grey limestone is packed full of fossils and the adjoining limy sandstones are replete with the same fauna. The limestone block contains Spirifer close to S. rutherfordi Warren, Martiniopsis sp. (superficially resembling Brachythyris suborbicularis (Hall)), Deltopecten sp., and Phillipsia sp. The adjoining hillside is composed of about 100 feet of dark grey, limy sandstone, which loses its lime cement through weathering and appears as a brown, fine-grained sandstone. It contains Spirifer cf. rutherfordi Warren, Martiniopsis sp., Deltopecten sp., and Euconispira taggarti (Meek).

There are probably about 200 feet of these beds exposed westward along the hillside, where they rise in a small anticline and are overlain by chert beds of the succeeding formation.

Six hundred and fifty feet up the hillside above mile 94 Dielasma sp. occurs in brown calcareous sandstone. This probably represents some beds of the "Mississippian" series.

There are two distinct faunas in these "Mississippian" strata, the lower one characterized by various productids and the upper one by spiriferoids. Neither of these faunas has much in common with faunas so far described from the Banff, Moose Mountain, Jasper, Peace River, or Liard River sections. Warren has listed Productus jasperensis, P. burlingtonensis, Dielasma chouteauensis, and two species of Brachythyris (but not suborbicularis) from the Banff shale at Jasper.

In comparison with the Illinois section, it is clear that both faunas are dominantly Osage (Burlington and Keokuk). Chester affinities are suggested by Chonetes chesterensis and Productus inflatus.

The spiriferoid fauna is higher stratigraphically. Its correlation would be with the Rundle or younger limestones of more southern sections, although the two faunas represent different facies, and have little in common.

Pennsylvanian or Permian

The rocks assigned to this age consist of black chert beds that weather grey or brown. They overlie the "Mississippian" series in the vicinity of miles 91 and 92. The contact is abrupt, but no structural discordance is evident, the relationship being disconformable.

The upper contact of the chert beds has not been seen. Triassic strata occur to the west, at mile 93, toward which the chert beds dip. The chert beds form a prominent hill to the north of the Highway exposures and appear to be 200 to 300 feet thick.

So far as seen, this formation consists entirely of black, hackly chert. Jointing has reduced the rock to angular masses that break out and form rough talus slopes. No fossils have been found in the cherts, nor do they appear likely to contain evidences of organic remains. Lithologically the chert beds resemble the upper beds of the Rocky Mountain quartzite of the Jasper Park area, which Warren dated as Pennsylvanian by analogy with the fossiliferous beds of Banff. Warren suggests an overlap at Jasper where the lower beds as represented at Banff are missing. The section on the Alaska Highway appears to represent a further overlap, as only the upper chert beds are present. Cherty beds occur in the Pennsylvanian beds of the upper Pine River Valley of the Peace River area, but until more detailed studies of that section have been made no definite correlation can be attempted. Chert beds 150 feet thick, overlain conformably by fossiliferous Permian sandstone, are exposed on Beaver River in southeastern Yukon[1] and may be correlative

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1 Kindle, E.D.: Geol. Surv., Canada, Paper 44-16 (1944).

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with the chert formation on the Highway section.

Triassic

Black shales, calcareous argillites, and calcareous sandstones outcrop in road-cuts and nearby hills between miles 94 and 101. Chert beds and hard sandstones are present in places, but all the rocks are high in lime, except in outcrops where the lime is largely dissolved out, leaving grey or light-coloured, saccharoidal sandstone. The formation is sharply folded and drift and forest cover obscure the section. Minimum thicknesses are indicated, however, in the anticlinal hills, which contain fossils of about the same age from bottom to top. One of these rises 1,600 feet above its base at mile 98. The broad section of outcrops of this formation suggests that the total thickness may be as much as 3,000 feet.

The age of these rocks is based upon a number of fossil collections made in the hills north of miles 93-94 and 97-98. At the former locality, and 650 feet above the Highway, Dielasmas were found in brown, calcareous sandstone. They suggest that Mississippian beds form the base of the hill, which is clearly faulted and folded. At the top of the hill the Nathorstites fauna is represented by Nathorstites mcconnelli Whiteaves, N. mcconnelli var. lenticularis Whiteaves, and Dielasma liardense Whiteaves. F. H. McLearn of the Geological Survey tentatively dates this fauna as later Middle Triassic[1].

[1] All Mesozoic fossils referred to in this report have been identified by McLearn.

North of miles 97 and 98 the following fossils were found in a road-cut: Daonella nitanae and Coenothyris cf. liardensis. About 1,100 feet up the hill Myochoncha cf. cauriniensis, Coenothyris cf. liardensis, Spiriferina cf. onestae, Daonella sp., and Ostrea sp. were found. At the top of the hill, or some 550 feet higher, Eumorphotis (?), Trigonodus, and Spiriferina were found.

Of the two lower lots of fossils McLearn reports "Although no specimen of Nathorstites or other determinate ammonoids are present, (the) two lots .... seem to be of the Nathorstites fauna, which is tentatively dated late Middle Triassic". Of other lots collected on the side of the hill he says, "(They) are probably of the same fauna, but the evidence is not so positive". Of the collection at the top of the hill McLearn reports "(This) looks unfamiliar and new. It is possibly of Triassic age".

Faulting and folding have confused the structure of the hill from which the above fauna was collected, but in general it appears that the higher beds on the hill should be higher in the section.

Grey, sandy shale, argillaceous limestones, etc., are exposed along the Highway between miles 87½ and 89½ and are included with the Triassic beds. This section is across a sharp anticline with axis parallel to the general strike of the region. Five fossil collections from these beds were examined by McLearn, who recognizes Ostrea sp. and Spiriferina? and says, of four lots, "(They) contain mostly indeterminate pelecypods, but may be of Triassic age. A fifth lot contains a few ammonoids and pelecypods including species of "Gymnotoceras", "Parapopanoceras", Monophyllites, Trigonodus, and Daonella. A tentative dating of early Middle Triassic is proposed."

The addition of this 2-mile section to the 8-mile section of Triassic rocks farther west suggests as impressive a column of Triassic rocks as that exposed along either Peace or Liard Rivers.

At mile 87½ the Triassic beds of the anticline (See map) are in juxtaposition with hard siltstone, presumably of Lower Cretaceous age. The crumpled condition of these beds suggests overthrusting. On the west side of the anticline, vertical dips prevail and another zone of crushing evidently lies between Triassic and Mississippian beds.

In the western section, Middle Triassic beds appear to be faulted against "Mississippian" beds in the hill north of mile 94, as the chert beds are lacking. The western side of the Triassic section, near mile 101, rests vertically against the faulted surface of Silurian limestones. Between mile 98 and the limestone front, black shales, cherts, and sandstones are included with the Triassic strata on lithologic and structural ground, as no fossils have been found in them.

Lower Cretaceous

Bullhead Group (?). The oldest Cretaceous beds recognized along the Alaska Highway are exposed between miles 85 and 87½. These beds consist of black, lignitic shale, hard siltstone, and sandstone.

The beds are crushed, folded, and faulted. On the west they lie close to the eastern side of a pronounced anticline in adjoining Middle Triassic strata. The variability of strike and dip of the two groups suggests a faulted contact at the front of the anticline, which is closely folded and faulted on its western limb. The absence of Upper Triassic and Jurassic strata would also lend support to the occurrence of such a fault were it not possible that beds of these ages may never have been deposited in this region.

Farther east, near mile 77, slumping sandstone occurs in a road-cut.

One poorly preserved Cardium sp. was found near mile 86 in dark grey sandstone. Lignitic beds measure as much as 4 feet in thickness, but no true coal was found. The proximity of those beds to the Middle Triassic rocks on the west suggests a low position for them in the Cretaceous section. Their relationships on the east are unknown, but they appear to assume the regular regional dip toward the east, and the broad valley of Mill Creek is suggestive of erosion of soft beds such as shales of the Fort St. John group. The assumed age is lower Lower Cretaceous, or about the equivalent of the Bullhead group of the Peace River area.

Fort St. John Group. The wide plains area extending 57 miles westward from Fort Nelson is underlain by soft, sandy, dark brown or black shale. Because of its softness it is rarely exposed along the Highway.

At mile 8 (R. Melville Smith Construction Camp) a small stream flows southward from a hill that rises 200 to 300 feet above the plain. The hill consists of black, sandy shale, with small concretions in some of the beds. A bore-hole, drilled for water, had penetrated to a depth of 208 feet in this shale. The formation here is nearly horizontal. At mile 27, black shale occurs in a road-cut, and south of mile 39 a large shale outcrop occurs in Kledo River.

West of mile 50 the Highway enters the Foothills, there consisting of horizontal dark shale. About 200 feet of shale is exposed between mile 50 and mile 51 where it is overlain by sandstone. The shale is nodular, commonly rusty weathering, with sheared vertical surfaces, striking south 50 degrees west. At the forks of Tetsa and Muskwa Rivers, south of mile 52, exposures of dark shale show in the banks. Along the old road, south of mile 54, a 500-foot section is in part exposed. This consists of several ledges of thin-bedded, grey-blue sandstone weathering buff, with covered intervals above and below strongly suggestive of shale interbeds. At the top of the section sandstone occurs interbedded with shale. Worm burrows are numerous on some slabs, and again near mile 53 and mile 54 on the new location of the road Posidonomya nahwisi var. moberliensis and P. nahwisi var. goodrichensis were found. Just below these fossiliferous beds poorly preserved plant remains and a 3-inch coal seam occur in the sandstone. McLearn correlates this part of the section with the Goodrich formation of Pine River Valley. At Commotion Creek this is classified as the second highest member of the Fort St. John group. Along the Highway south of Fort Nelson the shale is apparently continuous with the Buckinghorse formation of the same group (Hage, 1944).

To the west, the sandstone beds dip downward to a syncline, beyond which they rise gently into Teepee Mountain. This somewhat round-topped hill is situated between miles 60 and 61 on the new road and mile 61 on the old location. The strike of the strata varies from north to northwest, the dip being easterly at from $5\frac{1}{2}$ to 10 degrees. Pepper and salt sandstone outcrops along the road on the south side of the mountain, soft sandstone and shale beds continuing upward. About

1,100 feet up pepper and salt sandstones outcrop on the north side and continue upward, being more massive near the base of cliff-forming, massive, Upper Cretaceous conglomerate at 1,400 feet. This conglomerate continues to the top of Teepee Mountain, at an elevation of about 4,500 feet or 1,800 feet above the outcrops on the Highway near mile 60.

A more complete section occurs on the east flank of Steamboat Mountain and the ridge to the south. This is west and northwest of miles 63 and 64 on the old road location along Gardnor Creek. (At mile 64 old and new locations join.) The section appears to start in shale in the creek bottom at an elevation of about 2,600 feet above sea-level. Five hundred feet higher, concretionary shale outcrops and a sandstone ledge outcrops at 600 feet. In talus below this ledge a fragment of "Inoceramus" was found that resembles Posidonomya nahwisi var. goodrichensis. Ledges of sandstone outcrop at elevations of 3,450 to 3,500 and at 3,600 feet, with some 60 feet of intervening shale. Those beds form a decided cliff. The upper beds carry numerous worm casts. Ledges of sandstone outcrop at 3,800, 4,000, and 4,300 feet. Firm nodular shale occurs between the upper beds of sandstone. From about 4,300 feet coarse sandstone rises as a cliff 50 feet high to the base of massive, Upper Cretaceous conglomerate that forms an overhanging cliff on the east face of Steamboat Mountain. This conglomerate, with interbedded sandstone and lenses of sandstone, rises sheer for 500 feet. Massive upper beds overhang as much as 50 feet. Cones of huge conglomerate blocks piled up in front of the cliff record the cliff recession.

Piecing together the sections, the strata appear to comprise at least 500 feet of soft shale and sandstone overlain by cliff forming sandstones and interbedded shales carrying Inocerami. The sandstone formation is about 600 feet thick and is overlain by some 250 feet of shale, which underlies the massive beds of Upper Cretaceous conglomerate and sandstone.

The lower shales appear over so large an area between Fort Nelson and the foothills that their thickness is probably much greater than 500 feet, and may be upwards of twice that amount.

The group as a whole may be correlated with the Fort St. John group of Pine River, the lower shales corresponding to the Hasler formation, the middle, fossiliferous sandstones with the Goodrich formation, and the upper shales with the Cruiser formation.

Upper Cretaceous

The upper 550 to 600 feet of Steamboat Mountain is composed of massive sandstone and conglomerate. The basal beds are of hard, cream weathering sandstone, 50 feet thick, and the upper beds consist of massive conglomerate. The formation is cliff-forming, as may be seen in the east face of Steamboat Mountain. The upper massive conglomerate overhangs as much as 50 feet and the precipice is over 500 feet high.

Other outcrops of this formation occur on the top of Teepee Mountain, east of Steamboat, and on Table Mountain. In each case the resistant conglomerate beds control the slope of the upland surface.

The conglomerate on Teepee Mountain includes pebbles up to 2 inches in diameter. These consist of black chert, bleached yellow chert, white sugary quartzite, and opaque white quartz. One pebble of coarse-grained granodiorite was seen. Upward in the formation sandstone occurs.

On Table Mountain, the heavy conglomerate series is 550 feet thick. The conglomerate rests on soft clay shale interbedded with soft sandstone, with a bed of coal 1 foot thick near the top. The slumping and weathering of this soft formation has caused the recession of the plateaus, marked by the cliff fronts and the cones and piles of huge conglomerate blocks that occur at intervals from Table to Steamboat Mountains. Glacial moraines are interlocked with these boulder piles, showing that glacial ice has played an important role in the removal of surplus debris and in arranging what remains.

On the top of Table Mountain, near the eastern face, one huge cubic block of conglomerate appears to rest on one corner, forming a landmark visible from the Highway near Mill Creek.

The surface of Table Mountain conforms to the surface of the conglomerate, which dips about 6 degrees north by east. The conglomerate is cut into huge joint blocks, which, near the western precipice, have opened widely, leaving trenches 8 to 10 feet deep and 10 to 15 feet wide.

Other flat-topped hills to the north and northeast appear to be capped by the same conglomerate. The complete thickness of the formation is not represented at any locality visited, and must have been considerably more than 600 feet.

No direct evidence of the age of this formation has been found. It is clearly continental or deltaic, but no plant or other fossils were found. The coal bed just beneath its base records swampy continental conditions. By comparison with the sections in Peace River Valley, the formation may be correlated with the Dunvegan sandstone though it is much coarser and more massive than any Dunvegan known to the writer. It is, however, identical with the Upper Cretaceous, Fort Nelson formation that outcrops along Fort Nelson and Liard Rivers to the north[1].

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[1] Kindle, E.D.: Geol. Surv., Canada, Paper 44-16 (1944).

Tertiary

At Coal River, mile 250, Alaska Highway, large masses of brown lignite and slabs of lignitized wood lie scattered over the river bars. These were reported by McConnell, who failed to reach their source in the time at his disposal. The outcrop occurs north of the big bend in Coal River, and about 6 miles in a direct line from the Highway. The distance is much longer by the river.

The coal seam forms a rapid across the river, which is over 200 yards wide, and outcrops for about 300 yards along the river bank. In the west bank, 15 feet of lignite is well exposed, dipping 6 degrees to the northwest. The lignite weathers brown; some of it is very friable and some is tough and woody, containing large, well-preserved sections of logs. Ashy grey overclay shows in one place, but basal beds were not seen. In general the coal is overlain by a thick mass of outwash gravel.

Upstream, where the gravel cover has been removed by the river, the coal is burning over an area 150 yards along the stream and for 50 yards in width. Smoke and fumes are issuing freely from the surface, and trees and shrubs show all stages of death and destruction. Nodules of clay have been vitrified, and slumped overburden indicates subsurface collapse.

"Coal" is said to extend upstream as far as the "falls", but what distance that is can only be estimated. Hills could be seen approaching the river, some 2 miles upstream from the coal outcrops.

Downstream about $1\frac{1}{2}$ to 2 miles from the road, white clay outcrops in the west bank of the river at two localities. It extends upward from the river to a height of about 15 feet and is overlain by heavy gravel deposits. The exposures are about 200 yards apart and are each about 100 yards long. Evidently a considerable area is underlain by clay.

The relationship of the coal and clay deposits has not been determined, but they clearly belong to the same Tertiary basin. This is evidently several square miles in area, occupying Coal River Valley from its mouth for 8 to 10 miles upstream. Its width may be estimated as from 2 to 4 miles.

The age of the coal and clay deposits is certainly Tertiary, but to which division they belong is not known.

McConnell reported sandstone, clay, and lignite in the lower valley of a stream entering Liard River from the south about 7 miles below Hyland River. This locality was not visited by the writer. It is probable that several basins of Tertiary age may occur in this vicinity.

Glacial and Outwash Deposits

The Ice Age has left a legacy in the form of striae, glacial valleys, moraines, till, erratics, and outwash gravel and sand.

Glacial striae were noted as follows: on the north slope of Teepee Mountain (near mile 62 old road), direction south 35 degrees west; on the south side of Tetsa River, in the pass near mile 100, at an elevation of about 4,700, fine glacial striae on limestone, direction north 81 degrees east, in which direction the striae die out; on the southwest ridge of Mount St. Paul, elevation about 6,000 feet, direction of striae south 32 degrees west; and on calcareous argillite near north pier of suspension bridge over Liard River, fine glacial striae, direction south 62 degrees east.

The rock rims of the main valleys are typically U-shaped. Beautiful hanging valleys occur along Tetsa River and upper MacDonald Creek, and other tributary valleys have gorges and falls short distances back from their mouths. Side moraines have dammed hanging valleys along Tetsa River near mile 94, forming small lakes.

A mountain cirque facing MacDonald Creek Valley, about 2 miles south of mile 106, has a small moraine partly blocking its hanging entrance into the main valley. The elevation of the moraine is about 5,200 feet. Other perched north-south moraines occur nearby.

Glacial till occurs at numerous places along the sides of the valleys and up tributary channels, but it is largely replaced or masked by outwash gravels and sand. North of mile 98 a morainal knob occurs at an elevation of more than 4,700 feet.

Hoodoos carved from till occur in Summit Pass near mile 104, up a side stream entering Muncho Lake near mile 172, along Trout River near mile 193, and elsewhere. Till cements sufficiently to weather out into the picturesque boulder-capped columns known as "hoodoos", but outwash gravel and sand lack sufficient cohesion.

Erratic boulders are of interest as they indicate the source of at least a part of the till and outwash materials. Numerous red granite and gneissic boulders, in part cut by aplite dykes, occur along the Highway as far west as mile 95. The boulders here are fairly numerous and range up to 18 inches in diameter. Their identity with rocks from the Precambrian shield seems unquestioned. Tetsa Valley here is relatively narrow and is bounded by foothills rising to nearly

5,000 feet in height. The valley bottom has an elevation of about 3,300 feet and the distance from the Rocky Mountain front is only 5 miles. Eastward, pink granite and gneissoid boulders are more numerous. On Teepee Mountain (mile 64 circa) they occur above an elevation of 4,000 feet. On the other hand, boulders of Silurian limestone, of Silurian or Devonian sandstone, and of the local Pre-cambrian rocks indicate that the main drift was from the west. Valley glaciers account for the movement of rock debris from the mountains to the plains areas, but the origin of grey granodiorite boulders, apparently of Coast Range type, is not known.

Outwash gravel forms terraces of note along the valleys of the foothills and mountains. These deposits include till on their flanks and in places at the base, but they consist for the most part of well-rounded coarse gravel of local origin. Notable gravel terraces extend through Summit Pass (elevation 4,100 feet) to a height of about 4,700 feet. These terraces extend westward down MacDonald Creek to Racing River and eastward far down Tëtsa River. The present streams have excavated their channels into these gravels, in places well down to rock bottom. Elsewhere old channel bottoms may be several hundreds of feet below the present channel. The Summit Lakes and Muncho Lake are in dammed segments of valleys.

Similar terraces are well preserved along Trout River in the vicinity of mile 197. Gravel extends from the river level, at an elevation of about 2,250 feet, to an elevation of 2,400 feet. These examples are typical of the almost universal presence of terraces along the mountain valleys. Deep glaciated valleys were filled with till and outwash gravel mostly of local origin, and later, streams and rivers formed their present valleys and beds. How unstable are present conditions was well demonstrated during the floods of July 10 and August 2, when forested river bars were cut away, sand banks cut out, and river channels completely changed in a few hours time. Muskwa River near Fort Nelson is reported to have risen 30 feet in 30 hours.

Great sand plains, in part covered with shallow muskeg, extend eastward from the front of the Foothills, and Liard River Valley consists of broad terraces of sand plains below which the river has cut its present channels. Long stretches of smooth water are flanked by sand and gravel banks, and the intervening canyons mark the superposition of the present stream across spurs in the pre-glacial valley. West of Smith River, for more than 25 miles to the north, wide sand plains extend to undetermined distances. The outwash sand and gravel give some measure of the quantity of debris liberated by the retreating ice-sheet.

ECONOMIC POSSIBILITIES

Mineral Deposits

According to Dawson, Messrs. Thibert and McCulloch discovered gold near Fort Halkett in 1872. They also discovered gold in the Cassiar and a rush followed. The total yield for the district up to 1874 is reported as $1,000,000. In 1875 the yield was $830,000 and in 1876 the amount fell to $499,830. Gold was found on bars in Liard River as far down as 8 miles below the mouth of Coal River. As no separate record was kept of Liard River production, the values taken from the bars cannot be determined. Most of the gold obtained came from Dease River and Cassiar districts and recent prospecting along the Liard has produced little.

The northern Rocky Mountains, like their more southern counterparts, contain little in the way of mineral deposits. Purple fluorite occurs in Silurian (?) limestone near mile 107 and near the south end of Muncho Lake. Only small quantities were found.

The Precambrian slates, quartzites, etc., are cut by massive dykes of basic type, and show some quartz stringers and veins. The strata are generally rusty weathering, but mineralization is represented on a very small scale. As this formation is dated as Precambrian, it holds possibilities and deserves more attention, especially in the upper Toad River Valley and west of Muncho Lake. Trails lead into both of these areas.

The Pennsylvanian (or Permian) chert beds may be correlative with the Rocky Mountain quartzites of the more southern Rocky Mountains, in which phosphate deposits occur. The chert may be examined at mile 92 on the Highway. It outcrops in a narrow band, but extends northward into a hill of considerable size.

Coal

Sandstones and bituminous shales, classed as Lower Cretaceous in age, occur between miles 85 and 87. No coal has yet been found in them, but they appear to represent the northern extension of the Bullhead group of Peace River in which valuable deposits of high-grade coal have been found.

A 3-inch coal seam was seen in later Lower Cretaceous (Fort St. John) shale near mile 53, and a 1-foot seam of coal was found near the top of this group just beneath the Upper Cretaceous beds on Table Mountain.

An occurrence of brown lignite on Coal River has been described above. Masses of drift lignite, collected from the river bars, were used in heating the nearby army camp. A sample of this lignite was analysed by the Bureau of Mines, Department of Mines and Resources, Ottawa. The results are as follows:

		As Received	Dry
Moisture	%	15.4	
Ash	%	6.2	7.4
Volatile matter	%	45.6	53.9
Fixed carbon	%	32.6	38.7
Sulphur	%	0.3	0.3
B.T.U. per lb. gross		8,970	10,600

Non-agglomerating

Softening temperature of ash 2490°F.

Fuel ratio 0.72

The amount of coal accessible cannot be determined without extensive field work and drilling. At least 15 feet of lignite, such as represented by the analysis, outcrops for some 600 yards along the river bank and for the width of the river flats, or about 300 yards. The extent of the basin is about 10 miles by 2 to 3 miles. The direct distance from the Highway is estimated at about 6 miles, and road building along the west side of the stream would involve terracing along high gravel banks for a part of the distance. A winter road along the frozen river would be about 10 miles long.

Natural Gas

The similarity of the geological formations within the Foothills and Plains to those in areas farther south suggests the occurrence of natural gas and petroleum. Natural gas was found in the formations of the Fort Nelson area in drilling a well for water at the Muskwa airfield. The well is reported to have encountered a flow of 150,000 cubic feet of gas per day from sandy shale at a depth of 1,000 to 1,012 feet. The gas proved on test to be 98.4 per cent methane.

The presence of large volumes of gas in more definite structures to the west seems most probable.

Petroleum

The possibility of finding petroleum in the area of reference depends upon the presence of suitable formations. From a review of the above descriptions, it is evident that the Mississippian formations include argillaceous and arenaceous limestones of a type commonly petroliferous. Overlying chert beds of Pennsylvanian age are suitable as cover rocks. The thick Triassic arenaceous limestones also suggest porosity and similarity to petroliferous beds drilled in the Guardian well near Pouce Coupé. The Cretaceous beds show lignitic or coaly characters, and promise more in gas than oil content. Gas is already known to be present, but its high methane content gives small promise of association with petroleum.

Some structural features are worthy of note. For 50 miles west of Fort Nelson the structure of the plains, judging from outcrops, is nearly horizontal. Gentle domes might be determined by the seismograph. West of mile 51, southwesterly dips of 5 to 8½ degrees extend to a syncline at the base of Teepee Mountain. Teepee, Steamboat, and Table Mountains exhibit northeasterly dips of about 10 degrees. To the west outcrops are lacking in the broad valley of Mill Creek and for 10 miles beyond. There is a possibility that this valley may be anticlinal. High angles, crushing, and faults occur between miles 85 and 87, but the main character is anticlinal. Thus far Cretaceous measures are involved, but to the west Triassic strata rise in a pronounced anticline. Its front is crushed against Lower Cretaceous sandstones. The anticline takes the physiographic expression of a semi-cylindrical hill extending southeasterly, with axis parallel to the mountain front. The width of the fold is about 1½ miles and its western flank consists of vertical beds. Strata farther west consist of crushed argillites presumably of Mississippian age. At mile 91 vertical limestones and sandstones of Mississippian age occur. These and other outcrops represent a highly disturbed zone of Mississippian and Pennsylvanian beds that are succeeded westerly by a thick series of folded and crushed Triassic formations. These continue westward to the front of the mountains, where a high-angled fault separates Siluro-Devonian and Triassic strata.

From the standpoint of petroleum production, the more highly disturbed structures have little promise. Thus the pronounced anticline between miles 87 and 89 is faulted against Palaeozoic strata on the west, and is also faulted on the east. Structures farther west are generally badly crushed and faulted.

The structures east of the Triassic anticline (mile 87 and eastward to mile 85) are also considerably faulted, and for some distance beyond mile 85 no outcrops occur near the road. There is a possibility that the crushed anticline in Lower Cretaceous sandstones between mile 87 and mile 85 may have merit. The pressure from the anticline on the west may have concentrated hydrocarbons in the beds immediately to the east, and in that case some crushing and faulting might not be altogether inimical to oil accumulation. More work along the river bed near this locality and in the hills north and south might shed more light on the problem.

The wider, gentler structures near Steamboat Mountain deserve consideration and further work. Should a westerly closure be found west of Mill Creek, its valley offers promise. The dips are westerly between miles 51 and 60 on the old road and miles 51 and 54 on the new road, and mile 51 is evidently at the crest of a gentle anticline as the covered area to the east is apparently underlain by strata conforming to the regional dip, that is, easterly.

Drilling depths from horizons in the Cretaceous formations to the Triassic cannot be estimated with any degree of accuracy. From the Lower Cretaceous beds, in the vicinity of miles 85 to 87, the shallowest drilling is to be expected. As the Triassic is upthrust immediately to the west, it seems likely that 2,000 to 3,000 feet should be a maximum of Lower Cretaceous cover. Petroleum might here be found in the Cretaceous strata themselves, being driven into them from the adjoining Triassic beds to the west, in case these beds are petroliferous.

The main hope for petroleum production lies in the thick assemblage of marine, calcareous, argillaceous, and arenaceous beds of upper Palaeozoic and Triassic ages, and in their frontal relationship to the Rocky Mountains. A variety of structures is available, but a test location should be made only after careful field investigation.

Clay

Fifteen feet of greyish white clay outcrops below a gravel cover in the west bank of Coal River, from 1½ to 2 miles above the Highway. In all probability the area underlain is of considerable extent, as each clay outcrop is about 100 yards in length and the two outcrops are about 200 yards apart. The Tertiary basin is part of that in which the lignite occurs.

A 2-pound sample of the clay was submitted to the Bureau of Mines, Department of Mines and Resources, Ottawa, and the following report was received:

Nature of material - a buff-coloured, smooth clay that was found to be non-calcareous by the dilute hydrochloric acid test.

Water required to temper to stiff plastic state - 27 per cent.

Working properties - plastic, works well.

Drying behaviour - satisfactory.

Average drying shrinkage - 6 per cent.

Firing Behaviour

Cone	Fire Shrinkage	Absorption	Colour	Remarks
	%	%		
2(2075°F.)	6.7	4.0	Cream	Very hard
12(2390°F.)	5.4	0.0	Grey	Vitrified (overfired and bloated)

Softening point (Pyrometric Cone Equivalent) - 17

Approximate temperature - 2669°F.

Economic Considerations. From the limited amount of testing that could be carried out on the size of sample submitted, this clay is considered as having good possibilities for the production of such ceramic products as: sewer-pipe, pottery, stoneware jugs, bowls, etc., acid-proof brick, buff-coloured face brick, and other products for which a stoneware clay is required. Its refractoriness is too low for it to be of any value as a fireclay.

The close proximity of clay and fuel in the form of lignite is to be noted in making an appraisal of the possibilities of either of these materials.

Mineral Springs

Mineral springs are known at various localities in the area covered. Warm springs occur on the west bank of Toad River, a short distance above its junction with Racing River. These are reported as being relatively small and tepid. Warm springs are also reported on the north bank of Liard River about 2 miles below the mouth of Coal River. These appear to be small and of second-rate importance.

The best known springs are those located about a mile north-west from the north end of the Liard suspension bridge. Here, north of a large beaver pond on the west flank of a hill, several springs occur. The upper ones are quite cool, but have built up small basins and terraces of calcareous tufa. Just below these, a very hot spring issues from the ground. Alongside it the ill-fated Tom Smith built his cabin, and lived with his daughter Jane. The old cabin was torn down by United States Army engineers and two frame buildings were constructed, one over a small pool through which the water flows and one alongside for a dressing room. The water in this spring is said to have a temperature of about 121°F. To the north, and approached by a steep path, is a large open pool about 100 yards by 50 yards in dimensions. A tufa dam on its northwest side rises 60 feet from a beautiful valley. This pool has a soft mud bottom from which sulphur water bubbles. The temperature is reported as 110°F. Rough plank benches have been constructed alongside, and plank floats have been extended into the water for bathers. This pool is greatly appreciated by truck drivers and in fact by all who work along this part of the Highway.

Gallon samples were collected from each of the hot springs and are reported on by the Department of Mines, Victoria, B.C., as follows:

Submitter's Mark	Laboratory Report		
Lower Hot	CaO	29.2	milligrams per 100 c.c. of sample
Spring No. 1	SrO	1.3	"
Temp. 125°	MgO	6.8	"
Mi.213 Alcan	Na_2O	3.3	"
rd.-½ mile	SiO_2	5.7	"
north of			
Highway	Cl	2.3	"
from Tropical	CO_2	2.6	"
Valley	SO_3	50.5	"

Traces of: B,Mn,Pb, Fe, Al, Cu, Ag, Ni, Cr,Ba,Ti,K

Total solids on 100 c.c. sample dried at 103°C....... 119.5 milligrams

Total solids on 100 c.c. sample dried at
180°C....... 115.6 milligrams

Total solids on 100 c.c. sample ignited at
400°C....... 100.9 milligrams

Probable combination of major constituents:

$CaSO_4$	62.9	milligrams per 100 c.c. sample
$CaCO_3$	5.9	"
$SrSO_4$	2.3	"
$MgSO_4$	18.8	"

Submitter's Mark	Laboratory Report	
Upper Hot Spring No. 2 Temp. 90° Mi 213 on Alcan - ½ mi north of road from Tropical Valley	CaO 25.9	milligrams per 100 c.c. sample
	SrO 1.3	"
	MgO 6.5	"
	Na_2O 2.9	"
	SiO_2 6.5	"
	Cl 1.8	"
	CO_2 2.3	"
	SO_3 44.6	"

Traces of: B,Mn,Pb,Fe,Al,Cu,Ag,Ni,Cr,Ba,Ti,K

Total solids on 100 c.c. sample dried at
103°C ..... 105.5 milligrams

Total solids on 100 c.c. sample dried at
180°C ..... 101.4 milligrams

Total solids on 100 c.c. sample ignited at
400°C ..... 92.0 milligrams

Probable combination of major constituents:

$CaSO_4$	55.8	milligrams per 100 c.c. sample
$CaCO_3$	5.2	"
$SrSO_4$	2.3	"
$MgSO_4$	16.2	"

Signed ... G. Cave-Browne-Cave
Chief Analyst and Assayer

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